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Awareness and different forms of memory in trauma anaesthesia

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Awareness during surgery and memory for perioperative events may have substantial psychological consequences for the patient. The risk of awareness during trauma surgery is higher than during most elective procedures due to the fact that administration of adequate concentrations of anaesthetics is not always feasible. As a consequence, the risk of memory formation might be increased. The present review discusses different forms of memory, and the possibilities and limitations of awareness and memory prevention. *Curr Opin Anaesthesiol*

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Introduction

Although the incidence is low, awareness during surgery and memory for perioperative events are serious problems, notably because of the impact these events may have on the patient. Consequences of experiencing awareness include severe insomnia, feelings of terror, psychological trauma, and the risk of developing post-traumatic stress disorder [1,2•]. Even if conscious recall of the experience is fragmentary at first, cues such as seeing a hospital employee in a scrub suit during a postoperative visit may trigger memory of the whole episode [2•]. It is difficult, if not impossible, to assess the seriousness of the consequences in cases in which the memory trace remains inaccessible to conscious recall.

Before considering the different aspects of memory during trauma surgery, a short definition of the terms used to describe different forms of memory is provided, some of the advantages and disadvantages of different sorts of memory tests are explained, and the main difficulties of investigating memory during general anaesthesia are emphasized.

Memory, memory tests and the difficulty in assessing different forms of memory during general anaesthesia

Tulving [3•] argued that memory function is best conceptualized in terms of multiple memory systems. In the context of the present paper we focus on the measurable outcome of some of these memory systems rather than on the specifics of the functioning of these systems.

First, patients may be able to consciously recall perioperative episodes; they know what happened to them, when it happened and they can provide a verbal report about it. This form of memory is often termed 'explicit memory', although we prefer 'conscious recall' because of the somewhat greater precision of the term.

Unconscious forms of memory, on the other hand, include situations in which patients do not know that certain information is stored in their brain, meaning that they cannot give a verbal report. As a consequence, it is impossible for the patients to perceive when and how this information influences their behaviour. Controlled and uncontrolled unconscious memory are differentiated. Controlled unconscious memory comprises automatic behaviour such as making decisions based on previously learned information without being able to retrieve neither the exact information nor the precise

context in which the information was learned. Examples are not crossing a road if you hear a car approaching, or automatically taking the correct turns when driving to work. A large part of human behaviour can probably be regarded as controlled unconscious behaviour. Uncontrolled unconscious memory is a weaker form of unconscious memory and means that the learned information influences behaviour in an uncontrolled way. An example is being in a more positive mood after subliminal presentation (i.e. too short for conscious perception) of photos with smiling faces as compared with presentation of angry faces [4]. Both forms of unconscious memory are sometimes called 'implicit memory'.

There are different memory tests that attempt to measure conscious or unconscious memory. Direct tests attempt to capture conscious recall. Participants are usually asked to reproduce previously learned material, with or without being given a cue (cued versus free recall). Conscious recall of the learned information results in hit rates higher than some pre-established chance level (i.e. 'base rate'). Indirect tests are designed to measure unconscious memory. Examples are word-stem completion tests or reading speed tests in which speed in reading learned material is compared with that for unlearned material. In indirect tests, prior presentation of, for example, a list of words entails a priming effect, which in turn results in increased reading speed or hit rates that are higher than base rate. A serious drawback of both direct and indirect tests concerns the fact that performance might not exclusively depend on conscious recall and unconscious memory, respectively. The tests are not necessarily 'process pure' [5], meaning that performance on direct tests can also be influenced by unconscious memory and performance on indirect tests by conscious recall.

The process dissociation procedure has been developed to separate conscious and unconscious memory performance [5]. In one part of, for instance, a word-stem completion test, participants are asked to complete stems with previously learned words (inclusion part), whereas in the second part they are asked to avoid previously learned words and complete stems with other words (exclusion part). Suppose the base rate to complete the stem 'lim-' with the word 'limit' is 30% (i.e. without previous learning 'lim-' is completed with 'limit' 30% of the time by chance alone). In the inclusion part, both conscious recall and unconscious forms of memory will lead to hit rates higher than the base rate. In the exclusion part, however, only unconscious uncontrolled memory will result in higher hit rates. Conscious recall and controlled unconscious memory will cause hit rates lower than base rate. When using this test in an investigation of memory in trauma patients [6•],

we found that hit rates in both inclusion and exclusion parts were higher than the base rate, thus providing evidence for uncontrolled unconscious memory in trauma patients. Although originally the process dissociation procedure was designed to separate conscious from unconscious memory with the understanding that the decision to exclude words was necessarily conscious [5], we showed in a second study [7] that patients undergoing emergency caesarean sections under general anaesthesia were able to exclude words (e.g. the hit rate in the exclusion was lower than in the inclusion part) without being conscious of doing so. These results demonstrate that, in the absence of conscious recall, automatic decision-making can be based on information that was processed under general anaesthesia.

A key problem of investigating memory effects during general anaesthesia is to establish the source of memory. If short structured interviews are used in which patients are simply asked whether they recall anything from the operation, it might be impossible to find out whether the reported memory concerns preoperative, perioperative, or postoperative episodes. The problem can be solved by presenting words during surgery via headphones and assessing memory for these words postoperatively. A disadvantage of this strategy is that the content of the presented words is often neutral for ethical reasons. Consolidation of memory for emotionally arousing events, however, might depend on different processes or might be enhanced by different brain structures than memory formation for neutral words. Cahill and McGaugh [8] provided an interesting review on the role of stress hormones and the amygdala on memory for emotional events. Another disadvantage of word presentation and subsequent testing lies in the workload for the researchers. Because incidence of memory of perioperative events is low, large numbers of patients are needed if reliable estimates of incidence are to be established or if predictors of conscious recall or controlled or uncontrolled unconscious memory are to be investigated. As a consequence, incidence estimates are usually based on short structured interviews, thereby focusing mainly (but not exclusively) on conscious recall. Incidence of unconscious memory is much harder to determine, also because the estimation depends heavily on the sensitivity of the employed memory test. Usually, it is not known how many of the patients with unconscious memory are actually detected with the test.

Elevated risk of memory during trauma anaesthesia and incidence

In a large-scale study that investigated incidence of recall during general anaesthesia, associated factors and subsequent psychiatric disorders, Ranta *et al.* [9] provided clear evidence that low doses of anaesthetics are associated with an increased risk of awareness with

recall. Moreover, we demonstrated [6**] that the probability of uncontrolled unconscious memory in trauma patients decreased with increasing depth of hypnotic state. Administration of sufficient doses of anaesthetic agents to achieve an adequate depth may not always be feasible during trauma surgery, however, because anaesthetic dosage heavily depends on the patient's haemodynamic stability. This dependence places patients who are undergoing general anaesthesia for trauma surgery at an elevated risk of memory of perioperative events.

Although there are case descriptions of patients with memory of trauma surgery [1], the number of studies investigating memory during trauma surgery is very limited [10,11]. Estimates of the incidence of memory during trauma anaesthesia [12,13] are, for the main part, based on a well-known study carried out in 1984 by Bogetz and Katz [10] that investigated conscious recall of perioperative events on the basis of postoperative interviews. Assessment of the incidence of memory in the Bogetz and Katz study [10] relied on patients' self-reports and was estimated to be about 11% in minor trauma and 43% in severe cases. It seems safe to assume though that during the past 15 years resuscitation in the field has improved, thereby probably reducing the number of haemodynamically unstable cases, and, as a consequence, the average incidence of memory for perioperative events. The overall incidence of conscious recall in the study by Clemency and Thompson [11] was five out of 101 studied patients, and was higher in a group of patients who did not receive any anaesthetics for more than 15 min than in a group in which 'no-anaesthetic' episodes lasted less than 15 min [11]. Interestingly, all five patients with recall had received amnestics (see Prevention of awareness, below). In the most recent trauma study [6**] we controlled the origin of memory by presenting a list of words during surgery, and no convincing evidence was found for conscious recall. Of the 96 tested trauma patients, only one reported having been aware during surgery. This patient was not able to recall any of the presented words, however, nor did he show a pattern of uncontrolled unconscious memory in a word-stem completion test [14]. The average incidence of uncontrolled unconscious memory, as estimated using a word-stem completion test, in our study was approximately 10%.

Prevention of awareness

In cases of awareness during general anaesthesia, patients reported pain and helplessness due to inability to communicate their situation to be the worst part of their experience [2*,15]. Excessive use of neuromuscular blocking agents is a major cause of this problem. In the absence of full neuromuscular blockade, patients are able to signify awareness by moving an extremity or by

facial grimace. Hence, we recommend using neuromuscular blocking agents in the minimum amount necessary to facilitate surgery, especially when haemodynamic compromise restricts the amount of anaesthetic agents that can be administered.

Electroencephalography bispectrum monitoring is a recently introduced technology that can assist in guiding anaesthetic administration [16]. Bispectrum levels above 70 have been associated with recovery of consciousness during general anaesthesia [17]. The incidence of awareness with subsequent conscious recall during general (nontrauma) anaesthesia is about 0.2% (i.e. two cases in 1000). Data from cases using bispectrum monitoring suggest that the incidence of awareness with conscious recall is 25 cases in 800 000 (P. Manberg, personal communications), which is a 0.000003% incidence of reported cases.

Although prospective randomized trials are lacking, it seems to be reasonable to assume that maintaining bispectrum below 70 will result in a decreased incidence of awareness during trauma surgery. In cases where haemodynamic instability does not allow for administration of adequate concentrations of anaesthetic and when bispectrum (if monitored) is above 70, it is appropriate to communicate verbally with the patient and reassure them. According to patients' reports concerning episodes of awareness, verbal reassurance 'would have made a world of a difference' [2*].

Prevention of memory

Because administration of adequate anaesthetic dosage is at times not feasible, one might argue that administration of substances that are assumed to prevent memory should provide the solution to the problem. The memory-preventing effect of substances such as midazolam or scopolamine has not been unequivocally established, however. The trauma study of Clemency and Thompson [11] resulted in a somewhat paradoxical finding: the five patients who claimed conscious recall were in fact among the group of 49 patients who had been administered midazolam or scopolamine. None of the 51 patients who had not received amnestics claimed conscious recall. A study by Oxorn *et al.* [18] demonstrated no reduced risk for intraoperative dreams in a midazolam/propofol group than in a propofol group. With respect to scopolamine and lorazepam, Bishop and Curran [19] conducted an interesting study in which it was shown that both drugs have an anterograde effect on conscious recall, but not on unconscious memory as assessed using a category generation task. Consequently, it seems that these substances do not inhibit the processing of information, but they might decrease the probability of conscious recall. In a caesarean section study, in which midazolam was injected after having

shown the baby to the mother, midazolam was shown to have a retrograde amnesic effect [20]. Absence of recall of the baby's face was significantly higher in the midazolam group than in a control group. The question remains whether this retrograde effect concerns the destruction of a not yet consolidated memory trace or the access of processed information; in the latter case unconscious memory might still be present.

Trauma patients might be subject to a higher risk of memory formation, not just because of the sometimes inadequate anaesthetic dosage. Learning by association occurs if adrenaline is administered in animal studies [21,22]. Although this area of research is controversial [12], the possibility deserves consideration that catecholamines increase the probability of conscious recall or unconscious forms of memory. As mentioned before, stress hormones apparently play a modulating role in the consolidation of memory for emotionally arousing events [8]. In patients undergoing trauma surgery, very high levels of circulating catecholamines are likely (in addition to the exogenous administration of catecholamines by anaesthesiologists). Hence, memory formation may be enhanced in trauma patients.

Conclusion

Memory for intraoperative events can probably best be conceptualized as the result of an interaction of anaesthetic dosage, type of anaesthetic drugs, surgical stimulation and patient characteristics. In trauma anaesthesia it is not always feasible to administer adequate dosage of hypnotic agents. Reliance on drugs known for their effect on conscious recall such as midazolam, scopolamine, or lorazepam is problematic because they can not be assumed to suppress conscious recall adequately [11]. Also, certain forms of unconscious memory are apparently not influenced by these substances. A possible explanation for this differential effect might be that the different forms of memory rely on different memory systems [3*,8]. In the absence of conscious recall, unconscious memory for perioperatively presented neutral words has been shown to influence postoperative automatic decision making [7]. It is not known in which ways unconscious memory for an emotionally arousing event such as a period of awareness during surgery can affect subsequent behaviour.

Given the very small number of studies investigating memory in trauma studies, it is obvious that our present knowledge concerning this phenomenon is rather restricted. Further research may focus on identifying predictors of conscious recall other than anaesthetic dosage. This can be done in large-scale studies using short structured interviews in combination with available patient information. Relevant patient characteristics may

include history of drug tolerance, substance abuse and stress hormone levels.

With our current state of knowledge, the following suggestions may be useful in reducing the incidence of memory of painful events during trauma surgery. Adequate preoperative and perioperative fluid administration will improve haemodynamic status and allow for administration of adequate concentrations of anaesthetics and analgesics. Electroencephalography bispectrum monitoring can be used to guide anaesthetic administration and to identify periods of potentially inadequate anaesthesia. The use of neuromuscular blocking agents should be restricted to the minimum amount necessary to facilitate surgical exposure. Although benzodiazepines and scopolamine may reduce conscious recall, apparently they do not prevent unconscious memory formation. Also, the effect of these drugs might be paradoxical in trauma patients. Finally, it is always appropriate to talk to patients undergoing general anaesthesia and give general reassurance, especially when they may be paralyzed and aware.

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